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USE OF ELECTRIC POWER IN CASTLE GATE NO. 2 MINE, UTAH FUEL CO.

BY

D. J. PARKER

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By D. J. Parker[2]

INTRODUCTION

Owing to its flexibility, convenience, economy, and availability, electric power is peculiarly adapted to the needs of the coal-mining industry. Because of such obvious advantages, the application of electricity has in recent years become more and more extensive and is now a most important factor in the Nation's coal production.

With the introduction of this type of power into coal mines certain new, specific, and well-recognized hazards resulted. The question arises, therefore: Has the industry met these hazards squarely and effectively? With respect to some individual companies, the answer happily is in the affirmative; with respect to the industry as a whole, there is much room for improvement.

In order successfully to reduce the various hazards, including shock, burns, and gas- and coal-dust ignitions, with attendant fires or explosions, the United States Bureau of Mines has through years of effective research work established certain minimum safety standards relating to the construction of electrical equipment for use in coal mines, which have been met by many progressive manufacturers. As a result there are today available approved types of electrical equipment for almost every known underground use, including transportation, communication, illumination, mining, loading, pumping, etc.

In addition, the Bureau of Mines, in cooperation with mining officials and State mine-inspection departments, has fostered and promoted an intensive educational campaign looking to the elimination of electrical as well as other types of injury to employees of the industry.

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Electricity causes an average of 4 to 4½ percent of all coal-mine fatalities and ranks fifth in the causes of fatalities in coal mining; these figures do not, however, include fatalities from gas and dust explosions caused by electricity. The number of underground fatalities from the latter cause has increased 25 percent during the past 10 years.

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The author acknowledges his indebtedness to A. C. Watts, assistant manager, Utah Fuel Co., and to The Calumet Fuel Co. for much of the information on which this paper is based.

GENERAL DESCRIPTION

Castle Gate No. 2 mine is operating in the Castle Gate "D" bed, which averages 24 feet in thickness and dips on a 10 percent grade toward the north. The elevation at the portal is 6,131 feet above sea level. The cover ranges from a few feet to 2,500. This bed occurs in the Book Cliffs field, Mesaverde formation, Upper Cretaceous system.

Approximately 200 men are employed, and the average daily production is 3,000 tons.

Except for some hand loading and limited animal haulage Castle Gate No. 2 mine, under normal operating conditions, is completely electrified.

Because the mine produces more than 300,000 cubic feet of methane every 24 hours, and explosibility of the coal-dust is high, and the coal is easily ignited, unusual precautions have been taken to reduce existing hazards, including the selection, installation, and maintenance of electrical equipment, rock-dusting, adequate ventilation, closed lights, unstinted use of water, and good supervision.

SURFACE EQUIPMENT

Main Transformer Station

Current enters the main transformer station at 44,000 volts and is reduced to 4,000 volts. The station is substantially fenced, and the fence is provided with a gate which is kept locked at all times when not in actual use. Danger signs are posted. Switches, circuit breakers, and other necessary equipment are installed in a nearby concrete building, and rubber mats are kept in front of switch panels.

From this station the 4,000-volt circuit connects with the two outside motor-generator sets. A 4,000-volt cable enters the mine through the first left escapeway off the dips, and branch circuits are taken through the slope manway. A 440-volt cable also enters the mine through a cased drill hole at the top of the raises solely to supply power to the main hoist, located close by. A transformer in a well-guarded surface station near the collar of the drill hole reduces 4,000 volts to 440.

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The two motor-generator sets located on the surface produce 500 volts direct current for both surface and underground haulage.

The fan is operated by a 4,000-volt, a. c., 200-hp. motor, belt-connected. It is in a steel housing so arranged as to be well-protected from violence in case of an explosion.

UNDERGROUND TRANSFORMER STATIONS

Power enters the mine at 4,000 volts a. c. through a heavily insulated triple-conductor cable installed on the floor of the escapeway. Branch circuits connect with the various transformer stations. The 4,000-volt current is reduced to 440 and 220 volts. All alternating-current equipment is operated on 220 volts except the slope hoist, which requires 440 volts. The use of direct current is confined entirely to the operation of trolley locomotives.

The 12 transformer stations are at strategic points throughout the mine, and all are on intake air currents. The transformer rooms are of tile, with a concrete roof and floor; the latter is covered with about 6 inches of sand, which serves as an absorbent in case of oil leakage or spillage.

A steel door, so arranged that it will close by gravity and held open in nearly horizontal position by a hemp rope passing over the principal electrical apparatus, is standard equipment on all stations. This door, when closed, hangs at an angle of about 20° off the vertical, so that its own weight will keep it securely closed should the rope be burned through.

The electrical equipment in these stations consists of three 4,000- to 220-volt a. c. transformers, together with the necessary oil switches and circuit breakers. The transformer casings are well grounded and adequately guarded.

Each transformer station in the mine has an overload-relay switch. Short circuits in any section throw out the switch at the station transformer, and the lines to this station must be inspected and repaired before the switch can be closed. The rest of the mine on other transformer stations is not affected.

Not less than 2 cubic feet of rock-dust in metal containers are kept on the outby or fresh-air side of each station for fire-fighting.

From the transformer stations secondary cables, carrying 220 volts a. c. for the operation of portable equipment, lead to all sections of the mine. When it becomes necessary for the cables, either primary or secondary, to cross haulageways, this is accomplished by passing the cables under the tracks and through conduits consisting of short sections of 3-inch pipe.

All cables are laid close to the rib on the floor and are not suspended. They are protected from injury wherever they might be subjected to mechanical wear.

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The roof throughout virtually all parts of the mine where cables are laid is coal, and there is little or no sloughing or falls to damage the cables. If the roof were bad the cables would either be laid in ditches or suspended. It is preferable to bury them when there is any danger from roof falls.

CONNECTING TRAILING CABLES TO SOURCE OF POWER

It is almost general practice in mines where direct current is used for cutting and drilling to connect the positive conductor to the trolley wire by means of a hook or nip, the negative conductor being hooked to the rail. In moving a mining machine from one working place to another it is usual in coal mining to slide the nip or hook along the trolley wire to save time, and this practice of "nipping" mining machines has been responsible for many disastrous explosions. There is a record of 5 explosions from this cause in 1 mine, 3 occurring within 3 years, the last 2 less than 5 months apart.

Where alternating current is used it is customary in practically all mines, those of the Utah Fuel Co. excepted, to remove the insulation from a small area on the three separate conductors opposite each room neck to fasten the nips of the trailing cables thereto. Where this system is employed, short pieces of $\frac{3}{4}$-inch garden hose are sometimes placed on the conductors so that they may cover the bare places on them when trailing cables are not attached; this is the practice in some Utah mines. Numerous serious explosions resulting in fatalities have occurred from arcs caused when disconnecting the nips from the power circuit. The use of permissible junction boxes would eliminate, or at any rate greatly reduce, both the shock and the explosion hazard.

In Castle Gate No. 2 mine, where alternating current only is used for operation of portable equipment other than locomotives, the trailing cables of loading and mining machines and drills are connected to the secondary cables by means of "arctite circuit-breaking plug receptacles". These receptacles, the capacity of which is 600 volts-175 amperes, are so constructed that any arcing that may take place while the trailing cables are being connected or disconnected occurs before the sleeves of the male and female connections are separated; that is, the arcing occurs in a tightly enclosed space. Moreover, since the receptacles are close to the floor, if any arcing should occur, it is unlikely that accumulated explosive gas would be found close to the floor in an air course, usually in intake air.

Another desirable feature in connection with the secondary cables is a ground conductor in the form of a wire netting enclosed in the cable and connected to a circuit breaker in the transformer station.

The female section of the receptable is spliced into the primary cable at regular intervals, usually opposite every other room neck. The primary cable is carried along the floor on the opposite side of the entry from which rooms are turned.

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This system of supplying power to portable machines has proved to be safe because it eliminates open circuits, thereby reducing the shock and explosion hazards, and it is economical in that no supporting timber or insulators are required. It is rarely necessary to use timber along haulageways to support the roof material in advance workings.

DIRECT CURRENT

Castle Gate No. 2 mine is one of the few remaining mines of the west in which 500 volts are used. Storage-battery locomotives are used for gathering purposes to a limited extent.

The Utah Fuel Co. was the pioneer company in this State and introduced electrically operated locomotives into its mines about 1891. Since 1891 this company has operated at one time or another 8 mines in Utah and 1 in Colorado, all using 500-volt, d. c. locomotives, yet has had only one fatality from electricity (during the Sunnyside mine fire in 1921); this fatality resulted when a miner attempted to board the man-trip before the power was cut off the trolley wire.

In accordance with available information, the Utah Fuel Co. has undoubtedly established a record that might well be emulated, in that it has operated several rather thoroughly electrified coal mines over a period of 42 years with but one fatality from electricity and with no fatality from this cause from 1891 to 1921, a period of 29 years.

Incidentally, this company for a number of years was essentially a training school for mine officials, as evidenced by the fact that, as additional companies were formed in the district, mine foremen and superintendents in numerous instances were drafted from its organization.

The greater hazards involved, due to the use of 500 volts as against 250 or 275 volts on the trolley circuit, are well-recognized. A study of electrical accidents extending over a period of 2 years in one of the principal coal-producing States indicates that the liability of electrocution is approximately 4½ times greater at mines using 500 volts than at mines using 275 volts or less. This study indicates that electrical accidents tend to increase as the square of the voltage; that is to say, if the voltage is doubled, electrical fatalities are likely to be approximately quadrupled for the same number of exposures to the current.

No. 2 mine has never had a fatality from contact with the 500-volt circuit or any other circuit. The principal reasons for this excellent record are: (1) The trolley wire is well-supported and maintained uniformly 6½ feet above the rail. (2) Sectional circuit breakers are installed and used. (3) The power is shut off the trolley wire while the men are loading and unloading from the man trips. (4) All men are instructed regarding shock and fire hazards. (5) Constant and efficient supervision is in effect. (6) By virtue of the hazard itself a wholesome respect is commanded at all times and under all circumstances.

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It would appear that the immunity, up to the present, from electrical fatalities in No. 2 mine (when the relatively high voltage on the trolley circuit is taken into consideration) is not due either just to good fortune or good luck, or to any unbalancing of the equilibrium of the law of averages, but rather to well-directed and vigorous effort by the management to educate the personnel of the entire organization to think safety and work accordingly.

The media through which this has been accomplished are (1) monthly mass safety meetings, (2) regular foreman's meetings, (3) 100 percent first-aid training, not once but twice, (4) personal contact with the workmen by the foreman and subforemen, not infrequently, but several times during a single shift, and (5) rigid but fair discipline at all times.

SUGGESTIONS

In the interest of the 80 to 100 or more lives that are at stake annually in the coal mines of the country due to the use of electricity, a few fundamental rules, the application of which is vitally necessary if even reasonable safety is to be attained in the use of electricity in coal mines, will be repeated here.

The following suggestions are therefore offered in the hope that they may serve as an added stimulus to those responsible for the prevention of electrical accidents:

1. Every mine using electricity should be inspected at least once each year by a competent electrical engineer, who should make a written report of observed data on surface and underground installations and practices. The report should cover efficiency as well as safety. Preferably, such engineer should be familiar with underground mining, but not necessarily stationed at or near the mine.

2. In addition, monthly inspections should be made by the local electrician, who should submit a written report.

3. Surface and underground electrical systems should be installed and operated in accordance with suggestions given in U. S. Bureau of Mines Technical Paper 402, Safety Rules For Installing and Using Electrical Equipment in Coal Mines.

4. Because trolley circuits are responsible for most electrical contact accidents, as well as for many fires and explosives in coal mines, it would be desirable to substitute storage-battery locomotives for trolley-type locomotives, especially in gassy mines. In mines where trolley locomotives are used, they should be confined to main haulageways on intake air.

5. Where trolley locomotives are used, the trolley wire should be substantially guarded throughout its entire length wherever the trolley wire is less than 6½ feet above the rail.

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6. Trolley wires should be so placed as not to come in contact at any time with inflammable material, such as roof or rib coal, timber, brattice curtains, doors, door frames, etc.

7. Trolley wires should be installed in as straight a line as possible, about 6 inches outside the rail, 6½ feet or more above the rail, where feasible, and on the opposite side of the track from shelter holes or travelways.

8. Signal lines and telephone circuits should be installed on the opposite side of the haulageway from trolley or power circuits.

9. The necessity for maintaining slopes and haulageways, especially those carrying electricity, in a thoroughly rock-dusted manner is emphasized by the fact that several coal-dust explosions have been the result of wrecked trips dislodging the trolley wire or breaking buried transmission cables.

10. Danger signs should be posted conspicuously at points where such warnings will be the most effective in reducing possible contact with live or moving electrical apparatus. Such signs should specify the type of danger.

11. Instructions for the resuscitation of persons overcome by electric shock should be posted in every surface and underground station and hoist room, and also on the principal bulletin board, and all persons employed in or around mines should be kept well trained in methods of giving first aid to the injured.

12. Metal containers of not less than 2 cubic feet capacity should be kept filled with dry sand or rock-dust and located on the outby or fresh-air side of all underground electrical stations for use in case of fire.

13. In addition, fire extinguishers of the carbon-tetrachloride type should be available for combating possible electrical fires. Such extinguishers, however, should not be used in enclosed or confined places where there is little or no ventilation.

14. Incandescent lamps should not be permitted to come in contact with inflammable material. Only weatherproof, keyless-type lamp sockets with no exposed metallic parts, or equipment of equal or greater safety features, should be used.

15. All cables entering mines through boreholes or vertical shafts should be installed in accordance with the best-known practice and in such manner as not to bring unnecessary strains in the covering, insulation, or conductors.

16. All underground power circuits should be provided with sectionalizing switches at intervals not to exceed 2,500 feet. Such switches also should control all branch circuits from the main power lines.

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17. It is the practice in some mines to locate power circuits in return airways. Such location of power circuits in gassy mines is decidedly hazardous unless the conductors are carried in conduit or placed below the surface of the floor.

18. All electrical equipment, including conductors, switch gear, etc., should be of the very best material and should be installed in a first-class, businesslike manner.

19. Permissible electrical equipment only should be used, especially in gassy mines.

The foregoing are but a few of the numerous items that may be mentioned as necessary to safe installation and maintenance of electrical equipment. These deal largely with mechanical aspects of electrical hazards; of equal or greater importance is the human factor, which can be dealt with successfully only through education, discipline, and supervision.

CONCLUSIONS

Obviously, the responsibility for the prevention of electrical accidents rests almost entirely on the management rather than on the employee. There is, however, a definite obligation devolving upon the employee to exercise due care in avoiding such accidents as far as is humanly possible. The employer is responsible for the safe and proper installation, maintenance, and guarding of electrical equipment; furthermore, he is responsible for the education of the employee to the extent that carelessness, negligence, indifference, faulty judgment, and ignorance are reduced to the lowest possible degree.

There is probably less excuse for electrical accidents, than for any other cause of injury and death to workmen in the mining industry; the greatest number of fatalities from electric shock are caused by contact with live conductors, nearly all of which can be properly guarded with relative ease.

Our industrial progress and human welfare are based largely on the wise use of electric power. The demand for the application of ordinary common sense to curtail the many hazards incident to the use of electricity in mines has never been so great as it is today.

The progressiveness of the manufacturers has made it possible to procure, at small additional cost, safe, dependable, permissible equipment, the proper use and maintenance of which will go far toward reducing electrical hazards in coal mines.

The use of 4,000-volt highly insulated and protected power lines, as in effect in Castle Gate No. 2 mine, has given no trouble in transmission or leakage of current and has resulted in no accidents to date. The use of the auxiliary highly insulated 220-volt alternating power cables with the enclosed receptacles is both safe and efficient in itself and in addition requires the use of two men rather than one on mining machines, another safety feature very frequently not found in mines.

Unquestionably, the electrical installation in Castle Gate No. 2 mine is one of the most thoroughly safeguarded electrical installations in any coal mine in the United States insofar as probability of explosion ignition is concerned.

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